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A Prototype Submersible Electrofisher: Design and User Manual

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1992

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2143

Fisheries and Oceans Pêches et Océans

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Canadian Manuscript Report of Fisheries and Aquatic Sciences

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Canadian Manuscript Report of

Fisheries and Aquatic Sciences 2143

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A PROTOTYPE SUBMERSIBLE ELECTROFISHER: DESIGN AND USER MANUAL

by

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Cat. No. Fs 97-4/2143E ISSN 0706-6473

Correct citation for this publication:

Emmett, B., C. D. Levings, P. Kerfoot, and R. B. Lauzier. 1992. A prototype submersible electrofisher: design and user manual. Can. Manuscr. Rep. Fish. Aquat. Sci. 2143: 47 p.

93-00978/

ABSTRACT

Emmett, B., C. D. Levings, P. Kerfoot, and R. B. Lauzier. 1992. A prototype submersible electrofisher: design and user manual. Can. Manuscr. Rep. Fish. Aquat. Sci. 2143: 47 p.

A submersible electrofisher was developed to sample juvenile salmonids in river habitats during winter. The design and circuitry of the device are presented. Instructions for use by divers and safety precautions are given.

RÉSUMÉ

Emmett, B., C. D. Levings, P. Kerfoot, and R. B. Lauzier. 1992. A prototype submersible electrofisher: design and user manual. Can. Manuscr. Rep. Fish. Aquat. Sci. 2143: 47 p.

Un appareil submersible de pêche à l'électricité a été développé pour faire des prélèvements de saumoneaux en rivière pendant l'hiver. La conception et les circuits de l'appareil sont présentés. Les instructions d'utilisation par les plongeurs et les précautions de sécurité sont également données dans cet ouvrage.

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1.0 INTRODUCTION TO THE SUBMERSIBLE ELECTROFISHER

NOTE THAT THIS UNIT IS POTENTIALLY LETHAL IF OPERATED IMPROPERLY. IT IS IMPERATIVE THAT ALL OPERATORS READ AND UNDERSTAND THIS MANUAL AS WELL AS UNDERTAKE SPECIALIZED TRAINING IN OPERATING THE SUBMERSIBLE ELECTROFISHER.

DISCLAIMER

THE DEPARTMENT OF FISHERIES AND OCEANS ASSUMES NO RESPONSIBILITY FOR INJURY RESULTING FROM THE USE OF A SUBMERSIBLE ELECTROFISHER BUILT FROM THE PLANS GIVEN IN THIS PUBLICATION.

The submersible electrofisher has been designed to be operated in fresh water by divers appropriately equipped with SCUBA or snorkel equipment. Both the power and electrode units are submersible and operable at depths to 20 metres (65 feet). The electrofisher is portable and can be carried by the diver or placed on the bottom during electrofishing operations.

The submersible electrofisher is designed to sample fish habitat which is not accessible by conventional electrofishing equipment. This includes deep water or areas some distance from the shoreline which cannot be reached with backpack electrofishing equipment. The electrode configuration generates a contained electrical field which samples a small volume of water or area of bottom substrate. Voltages used are lower (<450 V) than conventional electrofishing equipment. In this way the submersible electrofisher can be used to capture individual fish or to sample specific areas of fish cover (twig debris or bottom substrate).

This manual reviews the basic theory of electrofishing, describes the submersible electrofisher and provides documentation for safe and effective operating procedures.

2.0 REVIEW OF ELECTROFISHING

2.1 BASIC ELECTRICAL THEORY

An understanding of the electricity and electric circuits is essential for persons using electrofishing equipment. This section provides a basic outlineof electrical theory; a more extensive review can be obtained in most college level physics texts. Kolz and Reynolds (1989) provide an excellent review of electrical theory as applied to electrofishing. A glossary of electrical terms is given in Appendix 1.

All physical material is composed of atoms, which contain a positively charged (+) nucleus surrounded by negatively charged (-) electrons. The three distinct charged particles associated with electrofishing are (1) **electrons**, (2) **positive ions**, (3) **negative ions**. These charged ions are the electrically active particles in water. Electrical energy is created by the separation of electrical charges between two terminals, the positive **anode** and the negative **cathode**. This creates a source of potential energy which can be recovered as heat, light or mechanical motion as electrical particles move between the cathode and the anode.

This potential energy is termed **voltage** and is measured in units called **volts (V)**. When the anode and cathode are connected via an electrical circuit electrons will flow from the cathode to the anode. The quantity of electrons moving per unit time is called the electrical **current** and is measured in **Amperes (A)**. The rate of movement of electrons is also a function of the material through which it flows. Certain materials such as copper and aluminum are excellent **conductors** of electrons. Electrons are poorly conducted by materials such as glass and air, which are generally called **insulators**. The measure of opposition to electron flow in materials is termed **resistance (R)** which is measured in units called **ohms**. **Conductance (G)** is the reciprocal of resistance

$$\text{Conductance (G)} = \frac{1}{\text{Resistance (R)}} \qquad (1)$$

and is measured in two synonymous units called seimens or mhos.

Current, voltage and resistance are mathematically related by **Ohm's Law**. The current in a circuit is directly proportional to voltage and inversely proportional to the circuit resistance:

$$\text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Resistance (R)}} \qquad (2)$$

In any electrical circuit if two of these parameters are known the third may be calculated using Ohm's Law. Digital multimeters can measure current, voltage or resistance in most

electrical circuitry.

Resistance is an indirect measure of the ability of electrons to flow through a substance, as it is usually calculated from Ohm's Law. Electrical **conductivity (c)**, not to be confused with conductance, can be directly measured in units of **siemens per centimetre**. The reciprocal of conductivity (c) is **resistivity (r)**. Conductivity meters are used to directly measure the conductivity of water during all electrofishing operations.

For three dimensional conducting substances (such as water being sampled by electrofishing) the total resistance required in Ohm's Law is related to conductivity by the following equation:

$$R \text{ (in ohms)} = \frac{d}{Xc} \qquad (3)$$

where: c = conductivity in seimens/cm
d = length of conducting material (in cm)
X = cross-sectional area of conducting material (in cm^2)

The calculation of resistance from conductivity measurements is complex but is simplified by substituting equation 3 into Ohm's Law and rearranging the equation:

$$V = IR = (I) \times (d/cX) \qquad (4)$$

$$V/d = (1/c) \times (I/X) \qquad (5)$$

Voltage gradient (in volts/cm) is defined as V/d and **current density** (in Amperes per cm^2) is defined as I/X. As conductivity and voltage gradients can be relatively easily measured in the field, these terms allow a practical measure of relating electrofishing success to the electrical output of the electrofishing equipment. See Kolz and Reynolds (1989) for further details.

Electrical current is generated in a variety of output forms. Most domestic electrical supply is in the form of **alternating current (AC)** where electron flow reverses at a specific frequency (60 Hz in domestic power supply). **Direct current (DC)** is the flow of electrons in a single direction, from the cathode to the anode. In many electrofishers the electrical current is **pulsed** (internally turned off and on) to generate a square wave pattern of electrical discharge (Fig. 1).

Power is a measure of the rate of electrical or mechanical work. Electrical power is measured in **Watts**. Power is related to voltage and current by the following formulae:

$$P = IV \text{ or (substituting Ohm's Law) } P = \frac{V^2}{R} = I^2 \cdot R \quad (6)$$

The effects on fish of electricity in water is power related; it is the electrical power experienced by the target fish, rather than voltage or current alone, which determines the fish reaction. When pulsed direct current is used for electrofishing the **peak power** (IV) determines fish reaction, although the total power output of the generating system is much less, (IV) x (t/T) in Figure 1.

2.2 ELECTROFISHING EQUIPMENT

Electricity has been used to capture fish in fresh water since the 1860's and much of the current literature on this topic was summarized recently in Cowx (1990). The theory and practice of electrofishing has been reviewed by Vibert (1967) and Bohlin et al. (1989).

The basic components of all electrofishing equipment are shown in Figure 2 and consist of:

1. Power Source - usually batteries or a gas-powered generator;
2. Transformer - which transforms generated power into a form usable for electrofishing (usually pulsed, direct current at 200-1200 volts);
3. Electrode Unit - which passes current through the water via an anode and cathode to induce involuntary swimming or to immobilize fish.

In many electrofishing systems the power source and transformer circuitry are housed collectively in the power unit.

2.2.1 Power output

Electrofishers can produce a variety of output parameters:

1. **Alternating current (AC).** It is generally acknowledged that AC current generates very strong contractions in fish musculature, which can cause permanent damage or mortalities. AC current is seldom used in modern electrofishing applications.

2. **Direct Current (DC).** In most electrofishing applications direct current is pulsed (Fig. 1). Pulse frequencies vary between 10-400 Hz and are often adjustable on electrofishing equipment.

PULSED DC CURRENT IS THE ONLY TYPE OF POWER OUTPUT AVAILABLE ON THE SUBMERSIBLE ELECTROFISHER.

2.2.2 Electrode unit

Using direct current, electricity flows through water from the cathode to the anode. Most effective electrofishing is achieved when the cathode size is at least three times the anode size. Larger anode diameters increase the effective fishing area and reduce the voltage gradient at the anode, thereby reducing fish mortalities. The anode/cathode configuration of the submersible electrofisher is somewhat different from conventional electrofishing systems as the intent is to sample a small, discrete area or volume.

2.2.3 Reaction of fish to pulsed direct current

Fish reaction to electrical current is affected by several factors which are summarized in Section 2.3 below. In general the reactions of fish to pulsed direct current can be classified into three general categories:

A. Flight. At low voltages fish will flee the electrical field area. With conventional electrofishing equipment this reaction often occurs at the periphery of the electrical field generated by the electrofisher. Voltages must be increased to a level which minimizes the flight reaction.

B. Galvanotaxis. At higher voltages fish will turn towards the anode and swim involuntarily towards it. This reaction is particularly useful when fish are in twig or substrate cover as fish will move from the cover towards the anode.

C. Galvanonarcosis. At higher voltages or as a fish approaches the higher voltage gradients near the anode it will become immobilized and turn on its side (galvanonarcosis), facilitating capture with a dip net. When the electrical power is turned off the fish will rapidly recover mobility (generally within 20-60 seconds). The galvanonarcosis reaction is desired to capture single fish using the submersible electrofisher.

2.3 FACTORS AFFECTING ELECTROFISHING EFFICIENCY

2.3.1 Conductivity

In general the conductivity of water depends on the quantity of dissolved ions

which are available to carry electrical current. In fresh water the efficiency of electrofishing increases as water conductivity increases and lower voltages are required to immobilize fish in water of higher conductivity. However if the conductivity of the water exceeds, by any great extent, that of the fish's flesh, negligible current will pass through the fish and electrofishing will be ineffective. For this reason electrofishing is not effective in brackish or marine waters.

OPERATION OF THE SUBMERSIBLE ELECTROFISHER IS EFFECTIVE IN WATERS WITH A CONDUCTIVITY OF 15 TO 400 µSIEMENS/CM (AT AMBIENT WATER TEMPERATURES). IT IS IMPERATIVE THAT WATER CONDUCTIVITY BE DETERMINED PRIOR TO COMMENCING ANY ELECTROFISHING OPERATION.

2.3.2 Water temperature

The conductivity of water decreases by 1.9-2.0% from each 1° decrease in water temperature. For electrofishing operations the conductivity of water should be determined at ambient water temperature. Many conductivity meters automatically compensate for water temperature, expressing conductivity at a standard temperature of 25°C. These meters should be corrected to ambient temperature to determine the uncompensated conductivity.

WATER TEMPERATURE SHOULD BE DETERMINED PRIOR TO COMMENCING ANY ELECTROFISHING OPERATION AND BEFORE MEASURING WATER CONDUCTIVITY.

2.3.3 Fish size

Larger fish experience greater head-to-tail voltage gradients than fish of smaller size when placed parallel to an electric field. Therefore larger fish require less power to immobilize than smaller fish. For this reason the voltage may have to be adjusted when sampling fish of varying size.

2.3.4 Pulse frequency

The frequency of pulsed DC power output is adjustable (10-400 Hz) in most electrofishing equipment. As a general rule higher pulse frequencies are more effective with smaller sized fish. With the submersible electrofisher a pulse frequency of 100 Hz has proven to be the most effective for fish approximately 100 mm in length.

3.0 DESCRIPTION OF THE SUBMERSIBLE ELECTROFISHER

3.1. GENERAL

The submersible electrofisher is a battery-operated unit housed in a submersible, laminated acrylic housing (Figs. 3-6). The transformer unit, laid out on a printed circuit board, is mounted to the clear plexiglass cover of the submersible housing. The total weight of the power unit, including batteries, is 9.5 kg. It is designed for use in low to medium conductivity waters (15-400 μsiemens per cm^3), and can generate up to 400 volts. Maximum operating depth is 20 metres (65 feet). Two different electrode units are available depending on the sampling application. Both audible (buzzer) and visual (neon light) signals indicate when the voltage output is triggered. The trigger control circuitry is electrically isolated from the high voltage electrofishing circuitry.

3.2 CONTROLS AND FEATURES (Refer to Figs. 3 & 4)

Submersible Housing:	A colour-laminate acrylic case (27 cm X 25.5 cm X 18 cm) with water-tight fittings for the trigger control and power output circuitry. A plexiglass cover, to which the transformer unit is mounted, is fitted to the case with eight bolts. A water-tight seal is provided by an o-ring mounted in the top of the acrylic case.
Power Source:	24 V, 6 Ah provided by two series connected 12 V gelled-electrolyte batteries.
External Controls:	Power on/off switch (case); voltage select switch (case); timer reset, magnetic (case); power output-enable (trigger handle).
Output Voltage:	Square pulse, externally adjustable from 0-400 V nominal (412 V measured, no load) in 50 V steps. Adjustment control mounted through the plexiglass housing cover. Peak power 942 W (peak) measured at a water conductivity of 220 μS (2.0 amperes of electrode current). 300 W (peak) maximum recommended.
Low Voltage LED:	A voltage-monitor circuit disables the electrofisher output and lights a blinking red lamp when the battery voltage falls below 21 V.

Power On/Off:	Power to the electrofisher circuitry is controlled by an on/off switch mounted through the plexiglass housing cover.
Output Trigger:	A magnetic reed switch inside the trigger handle is activated by depressing the trigger (which contains a small magnet). The reed switch turns on the high voltage power supply and the output pulse circuitry. The trigger is a "deadman" switch design; when the trigger is released the output circuit is turned off.
Power LEDs:	Power output is monitored by means of three LEDs mounted on the circuit board. These lights come on when the output circuitry is triggered. Amber = ineffective power; green-effective power; red - excessive power. Effective power is obtained by adjusting the output voltage level.
Timer:	An LCD timer clocks electrofishing time, based on the amount of time the trigger circuitry is activated. The timer clocks in hundredths of a second and, in most applications, the last two digits on the timer can be disregarded. The timer is reset by passing a magnet over the timer reset switch on the left hand side of the timer.
Visual Power Indicator:	A neon lamp mounted on the circuit board indicates when the output trigger has been activated.
Audio Power Indicator:	A pair of buzzers, mounted in the trigger handle, are also activated handle, are also activated when the output trigger is depressed. These buzzers provide an audible signal underwater to both the operator and assistant, without diverting attention from electrofishing activity.
Pulse Frequency:	Internally switch-selectable frequencies with a fixed duty cycle of 12.5%: 40 Hz; 80 Hz; 120 Hz; 160 Hz; 200 Hz. The adjustment switch is mounted on the underside of the printed circuit board (Fig. 4).
Charger:	A modified Smith/Root 24 V charger is provided for charging batteries. See Section 5.3.2 for battery charging instructions.

These features are summarized as a block diagram in Figure 5. A more detailed description of the electrical circuitry, including circuit diagrams, is given in Appendix 2.

3.3 ELECTRODE UNITS (refer to Figs. 6-7)

Electric current is passed through the water from the negative cathode to the anode. Two anode/cathode configurations, which are used in different sampling applications, are available for the submersible electrofisher. Both electrode units screw into the output trigger handle and the power output wire is connected to the anode and cathode with wing nuts.

THE RED-MARKED LEAD IS CONNECTED TO THE ANODE AND THE BLACK MARKED LEAD IS CONNECTED TO THE CATHODE.

3.3.1 Quadrat electrode unit (Fig. 6)

The quadrat electrode unit is used to sample fish from bottom substrate (gravel/cobble/boulder). Fish often move into the interstices of rocky substrate, particularly during the day in the winter. The quadrat electrode has been designed to sample a discrete area of river bottom (0.5 m^2). The cathode consists of a 0.7 m X 0.7 m square of aluminum tubing. The 10 cm diameter anode is mounted 14 cm above the cathode by three flexible spacers. In this way, when output power is triggered, fish are induced to swim involuntarily from the substrate towards the anode. Operation of the submersible electrofisher using the quadrat electrode unit is described in Section 5.2.2.

3.3.2 Wand electrode unit (Fig. 7)

The wand electrode unit is used to capture free swimming or stationary fish. The anode and cathode are made of perforated aluminum plates mounted 34 cm apart on a Delrin plastic handle. The electrical field is confined by backing the anode and cathode with plexiglass shields. As the anode/cathode geometry is symmetrical, either aluminum plate can be used as an anode or cathode. At the appropriate voltage setting the wand electrode unit induces rapid galvanonarcosis in the target fish, facilitating capture with a dip net. Operation of the submersible electrofisher using the wand electrode unit is described in Section 5.2.3.

4.0 SAFETY PRECAUTIONS FOR SUBMERSIBLE ELECTROFISHING

All electrofishing equipment produces sufficient voltage and current to produce dangerous and potentially lethal electric shock. This is also true for the submersible

electrofisher, although the power output is less than other electrofishing systems. The use of snorkelling or SCUBA in conjunction with the submersible electrofisher compounds the risk and hazard level.

ALL PERSONNEL MUST BE PROPERLY TRAINED BEFORE USING THE SUBMERSIBLE ELECTROFISHER, AND THE EQUIPMENT MUST BE TREATED WITH RESPECT AT ALL TIMES. THE MOST OBVIOUS BUT BASIC RULE IS NEVER TO TOUCH THE ANODE OR CATHODE WHEN THEY ARE CONNECTED TO THE POWER UNIT.

OPERATING PROCEDURES FOR USING THE SUBMERSIBLE ELECTROFISHER HAVE BEEN REVIEWED BY THE WORKERS COMPENSATION BOARD OF BRITISH COLUMBIA (SEE APPENDIX 3). HOWEVER THE DEPARTMENT OF FISHERIES AND OCEANS ADVISES THAT EXTREME CAUTION MUST BE USED WHEN OPERATING THE SUBMERSIBLE ELECTROFISHER.

The following standards are recommended for all persons using this submersible electrofishing equipment:

1. The field crew must be certified in the operation of electrofishing equipment. Training courses, with certification to B.C. government standards, are given by Malaspina College, Nanaimo, B.C. A review of safety standards for operating electrofishing equipment is given by Goodchild (1991). A high level of field experience with conventional electrofishing equipment is also required. Specialized field training in the safe use of the submersible electrofisher is required for all electrofishing field personnel.
2. When used in conjunction with either snorkelling or SCUBA equipment all diving personnel must be certified in SCUBA diving and have a minimum of 100 hours of logged dive time.
3. All persons operating the submersible electrofisher should have an annual medical examination, with attention to heart function. All electrofishing crew members must be trained and currently certified in CPR and basic first aid.

4.1 Safety procedures

When operating the submersible electrofisher the following procedures are essential:

1. All diving personnel must wear a drysuit (either neoprene or ultralight), including hood and 3-finger gloves. Use of a wetsuit while operating the submersible electrofisher is NOT PERMITTED.
2. Never operate the submersible electrofisher when alone.
3. Never operate the submersible electrofisher without shore or boat support.

4. Always measure the water conductivity and temperature prior to operating the electrofisher and do not operate at excessive voltage levels.
5. Never touch the metal anode or cathode (either gloved or bare-handed) when the electrode unit is connected to the power unit. When the power unit is out of the water ensure that the power is off and the voltage setting turned to zero.
6. Operator and assistant should always be situated downstream of the electrofishing area and the electrofishing operation should proceed in an upstream direction.
7. Do not allow the electrode unit to drag on the bottom when moving underwater. Carry the electrode unit to avoid accidental triggering of the power output.
8. WHEN THE POWER OUTPUT IS TRIGGERED KEEP ALL PARTS OF THE BODY (INCLUDING HANDS AND FACE) MORE THAN 20 CM FROM THE ANODE AND CATHODE.
9. Always inspect the trigger and power output cables, as well as the acrylic case for damage prior to each electrofishing operation. When the unit is first placed in the water inspect the housing cover o-ring seal for any sign of leakage.
10. Remove wristwatch, rings and any other jewellery when handling batteries. A battery is capable of producing very high current that can severely burn.
11. Do not smoke or permit flames or sparks near a battery at any time, particularly when it is charging.
12. Have electrical circuits serviced only by qualified technicians.
13. Disconnect the battery when the electrofisher is not in use.

5.0 OPERATING PROCEDURES

5.1 PRE-OPERATIONAL

Before each field use a general inspection of the submersible electrofisher should be made. Inside the housing ensure that the batteries are properly seated and adjust the tightening screws on the plexiglass seating plate if necessary. Inspect the internal lead wires and intermediate couplings. Externally make sure the brass seating nuts for the trigger and power output wires are hand tight. Inspect the housing for cracks or faults where leakage might occur. Inspect the trigger and power output wiring for nicks or cuts which could result in a short circuit or leakage into the housing.

5.1.1 Lead connections

Prior to sealing the unit ensure that all leads inside the unit are properly connected (Fig. 4). There are four plugs on the circuit board, each with a different number of connecting pins.

connecting pins.

TO ENSURE CORRECT POLARITY THE PLUGS SHOULD BE CONNECTED WITH THE WIRES ON THE FEMALE SECTION OF THE PLUG FACING AWAY FROM THE PRINTED CIRCUIT BOARD.

The trigger circuitry is connected via the three pronged plug and the power output circuitry connected via the five pronged plug. Both these plugs should remain connected between each field use.

The two pronged plug and lead is the connection for the battery charger. Prior to sealing the unit ensure that the battery charger lead is capped with provided plug. The four pronged lead (on the right side of the circuit board in Fig. 4) is the connection to the battery. This connection should be unplugged during storage and transportation to ensure that the power circuitry is interrupted should the electrofisher be turned on accidentally.

5.1.2 Sealing the unit

Inspect the o-ring for grit, small cuts and nicks. The o-ring should be lubricated with a thin coat of a silicon based grease. Only silicon greases should be used as other lubricants may deteriorate the o-rings. Silicone grease is available at dive shops or laboratory supply companies.

The unit is sealed by placing the plexiglass cover into the eight studs on the top of the submersible housing. The nuts are then screwed hand tight and each nut given an additional half to full turn using a 3/8" box wrench. Tighten the nuts in opposing sequence. The o-ring should appear slightly flattened against the plexiglass cover.

DO NOT OVERTIGHTEN AS THIS WILL UNDULY WEAR THE O-RING SEAL. CHECK AGAIN TO ENSURE THAT THE POWER IS OFF AND THE VOLTAGE SET TO ZERO.

5.1.3 Pre-dive procedures

ENSURE THAT THE POWER IS OFF AND THE VOLTAGE SET TO ZERO.

Measure and record the water temperature and conductivity in the area where electrofishing operations will take place. The appropriate electrode unit can be screwed into the trigger handle and the power output leads connected to the electrode unit (Figs. 6-7).

WHEN USING THE QUADRAT ELECTRODE UNIT ENSURE THAT THE

POSITIVE (RED) LEAD IS CONNECTED TO THE ANODE AND THE NEGATIVE (BLACK) LEAD IS CONNECTED TO THE CATHODE.

Prior to entering the water set up the electrofisher for the appropriate electrode unit. If bottom substrate is to be sampled using the quadrat electrode unit, uncoil the 5 m of lead wire to the electrode unit for maximum working scope. The sealed power unit is positively buoyant unless weighted with lead weights. For nearshore work or in shallow, calm water the power unit can be placed on shore or floated at the surface. In fast current or deeper water the power unit is kept on the bottom by strapping a weight belt with 2-3 kg of lead around the submersible housing. Lead weights can also be made to screw into the bottom of the housing.

Using the wand electrode unit, the trigger and power leads should be coiled to provide a 3-4 foot reach with the wand. If sampling fish in the shallow nearshore by snorkelling the submersible housing can be clipped to a dive belt or strapped to a tank backpack. In deeper water, using SCUBA, the unit should be weighted with about 2 kg of lead and clipped to a second quick release belt (NOT THE WEIGHT BELT) around the divers waist.

When the electrofisher has been set up, test the functions by submersing the anode and cathode in the water, turn the power switch on, keep the voltage setting at zero and depress the power output trigger. Check the unit for timer function, battery power level, neon power indicator signal and the audible buzzer in the trigger handle.

TURN THE POWER OFF BEFORE ENTERING THE WATER AND RESET THE TIMER TO ZERO.

5.2 OPERATIONAL PROCEDURES

5.2.1 GENERAL

After entering the water and reaching the sampling area, inspect the o-ring seal and housing for any sign of leakage such as moisture seepage on the inside of the o-ring seal or air bubbles escaping through the o-ring seal. If no sign of leakage is discernable the unit should be powered on in the following sequence:

a. ensure the voltage setting is at zero
b. turn the power switch on
c. increase the voltage in 50 V increments until the green power LED indicates effective electrofishing power
d. ensure that the power output buzzer signal is audible to both the operator and the assistant

Note 2. Using the quadrat electrode in low conductivity water (10-75 uS) it may be necessary to increase voltage until the power indicator flashes both green and red.

Note 3. Under certain conditions it may be more feasible to turn the unit on and adjust the voltage level prior to entering the water. However, care must be taken to prevent accidental trigger discharge while entering the water. This procedure has been used when using the wand electrode while snorkelling in nearshore margins.

5.2.2 Sampling using the quadrat electrode

TO SAMPLE FISH FROM BOTTOM SUBSTRATE A TEAM OF TWO IS DIVERS IS ALWAYS USED; an operator who conducts the electrofishing operation and an assistant who nets fish and turns over substrate in areas previously electrofished to look for fish within the substrate. The procedure is as follows:

1. Diver and assistant position themselves and the electrofishing equipment downstream (or downcurrent) of the sample area.
2. Turn on the electrofisher and adjust voltage as described in Section 5.2.1.
3. Place the cathode quadrat on the substrate and trigger the power output 2 or 3 times in approximately 5 second bursts.
4. The assistant is positioned next to the diver, ready to dipnet fish emerging from the substrate. Netting of fish should take place when the output trigger is off (e.g. no audio output signal), unless the fish have drifted at least 20 cm from the cathode perimeter.
5. The electrofishing operation moves in an upstream direction through the sample area. The assistant follows, looking for immobilized fish by turning over substrate in areas where electrofishing has just been completed.

DESPITE ALL TEMPTATIONS, NEVER TOUCH THE ANODE AND CATHODE DURING ANY PART OF THE ELECTROFISHING OPERATION.

Note 1. WHEN THE POWER OUTPUT IS TRIGGERED KEEP HANDS AND FACE A MINIMUM OF 20 CM FROM THE PERIMETER OF THE CATHODE QUADRAT.

Note 2. The operator and assistant should always remain in visual contact and BOTH must be able to hear the audio power trigger buzzer.

Note 3. Use non-conductive material for a dipnet.

Note 4. In shallow water the assistant can carry captured fish in the dipnet to the shore or boat support team. In deeper water the assistant should carry a catch bag to retain captured fish.

5.2.3 Sampling using the wand electrode

The wand electrode is used to capture fish in a manner similar to a spear gun or trident except that the fish is unharmed by the sampling method. This method has applications for sampling fish to determine microhabitat parameters, collection of fish for length, weight and scale sampling as well as the identification of prey items by stomach pumping techniques. The wand electrode has been used to capture fish during the day and at night. At night, using dive lights, salmonids are easily approached and caught. Preliminary results of surveys for juvenile chinook in the Nechako River were conducted using the submersible electrofisher in February 1990. Results are presented in Emmett and Convey (1990).

Using SCUBA the submersible electrofisher and wand electrode should be operated with two divers; an operator and assistant as with the quadrat electrode. In some applications the wand electrode is used in the shallow, nearshore zone (less than 2 metres from shore) and only the operator enters the water, supported by a shore crew of one or two persons, appropriately equipped with chest waders and rubber gloves.

The sampling procedure is to slowly and quietly approach the fish, moving the wand electrode so that the fish lies between the anode and cathode plates (see Fig. 7). At night salmonids often remain immobile when kept in the beam of a dive light. As fish are very sensitive to vibration, avoid striking the electrode or power unit on the bottom when approaching fish. Triggering the power output for one second or less is sufficient to induce galvanonarcosis if the fish is properly positioned between the anode and the cathode. The fish is collected with a non-conductive dip net.

Note 1. Always hold on to the wand electrode when moving or drifting to avoid accidental discharge of the trigger handle.

Note 2. The outside of the anode and cathode plates are protected by a plexiglass shield.

DO NOT REACH BETWEEN THE ANODE AND CATHODE TO NET FISH UNLESS THE TRIGGER IS OFF (NO AUDIO SIGNAL).

Note 3. Voltage should be set so that the green (effective) power LED lights when the power output is triggered. This voltage level should be effective in both low and medium conductivity waters. However, should fish escape, increase the voltage setting by one or two steps. If the fish require more than one minute to recover from the galvanonarcosis, reduce the voltage setting. Recovery times may be greater at water temperatures less than 5°C.

5.3 POST OPERATIONAL PROCEDURES

5.3.1 On-site

After sampling has been completed return the voltage setting to zero and turn the power off. In most cases this should be done while the electrofisher is still in the water. The electrofisher can then be passed to the boat or shore crew, who complete the following steps:

1. check that the voltage setting is at zero and the power off
2. record electrofishing time and reset the timer if necessary
3. disconnect the power output leads to the electrode
4. unscrew the electrode from the trigger handle
5. visually inspect the housing, electrode and wiring for signs of damage or leakage

5.3.2 Battery charging

Following each field use the submersible housing should be opened to dry any condensation. The battery is charged by plugging the two pronged lead from the circuit board (Fig. 4) into the Smith-Root charger lead. Ensure that polarity is correct by matching the red sides on both lead plugs. The housing cover should be propped against the housing studs to ensure adequate ventilation within the housing during charging. Then plug the charger into a wall socket. The red LED light indicates charging, and the green light a charged condition. When charged, unplug the charger from the wall, then unplug the charger from the two pronged circuit board charging lead.

Note 1. Never completely discharge these batteries. If stored for an extended period in a discharged condition there is a risk that the battery cannot be recharged. The battery should be fully charged before being placed in storage (to compensate for self-discharge).

Note 2. Do not use a high capacity automotive charger to charge these batteries. Charging at an excessive rate (high amperage) and overcharging for prolonged periods result in electrolysis of the battery's water and internal heating, resulting in gassing and premature drying.

Note 3. Batteries charged in series must be of the same type and in the same condition: age and state of discharge (i.e., should be a 'matched set').

Note 4. Lead-acid batteries evolve hydrogen during charging. Ensure adequate ventilation and keep the batteries from sparks or flames during charging. Never charge the batteries with the housing cover firmly seated to the housing.

Note 5. Refer to Section 6.3 for technical details of gelled-cell batteries.

6.0 MAINTENANCE, TRANSPORTATION AND STORAGE

6.1 HOUSING AND EXTERNAL WIRES

The acrylic-laminate case is extremely strong, but can be shattered or cracked if dropped or otherwise abused. Avoid placing the housing where it might fall and fracture. Examine the housing routinely for cracks or fractures. If the electrofisher is used extensively in shallow, fast-moving water and is subject to bumping on the bottom substrate consider protecting the housing with a cushioning material such as ensolite. The o-ring seal should be inspected regularly and replaced when it becomes nicked or flattened by overtightening of the plexiglass cover nuts.

The external power and trigger wires should be replaced at the first sign of nicks or cracks which could permit water to leak under the black shielding cover. The wires are disconnected at the intermediate coupling inside the housing (Fig. 4). The brass nuts on the outside of the housing are then unscrewed and the wires removed from the housing. When fitting new wires replace the o-rings on the wire at the inside of the brass nut and re-lubricate with silicon grease.

6.2 CIRCUIT BOARD

The electronic circuitry is maintenance free. Should there be any problems with the operation of the electrofisher refer to Section 7.0 - Troubleshooting. If the problem cannot be rectified by referring to the Troubleshooting Section it should be returned to the manufacturer for repair.

6.3 BATTERIES

Battery charging procedures are described in Section 5.3.2. Refer to Note 1 in this section. Gelled-cell batteries should be stored fully charged. Avoid fully discharging these batteries in the field and never store batteries in the discharged condition.

The following is a short collection of data, recommendations and warnings from manufacturers of gelled-electrolyte batteries.

These batteries use lead-calcium electrodes and an acid electrolyte in a gelled or otherwise immobilized form contained in a vented, shatter-resistant case. Their advantages compared to nickel-cadmium cells are superior low temperature performance and greater resistance to neglect and abuse.

Life span	300 - 500 'normal' charge/discharge cycles.
Voltage charge end point	2.3 to 2.4 V per cell (13.8 to 14.4 V for a '12 V' battery)
Charged terminal voltage	2.12 V per cell (12.72 V for a '12 V' battery).
Float charge voltage	2.25 to 2.3 V per cell (13.5 to 13.8 V for a '12 V' battery).
Maximum charging current	0.1 to 0.15 times the battery's Ah (ampere hour) capacity.

Capacity VS Temperature:

(When the battery is charged at 20°C)

Temperature (°C)	Approx % of 20°C Ah Capacity
20	100
10	94
0	86
-10	78
-20	68

The Smith-Root BC-24 battery charger included with the submersible electrofisher is one in which the output current and voltage are controlled. This, in combination with the submersible electrofisher low-battery detection circuit and user care in battery handling and storage, should extract the maximum lifespan from the batteries.

6.4 TRANSPORTATION AND STORAGE

During shipping the battery power plug (4 pronged) should be disconnected. The housing should be packed to prevent damage should the shipping box be dropped. Store the submersible electrofisher in a dry area and follow the instructions for long term battery

storage outlined in Sections 5.3.2 and 6.3.

7.0 TROUBLESHOOTING

Note: Wait for one minute or longer after the submersible electrofisher was last triggered before investigating circuitry. Refer to circuit plans in Appendix 2.

1) Electrofisher has no apparent effect on fish; no buzzer or visual indicators.
   (a) Faulty battery cabling. If the 10A fuse located on the board appears to be intact, this is the probable cause. Check the 'fast-on' terminals on the battery and connections to the 4 post terminal J1 on the underside of the printed circuit board.

   (b) Blown 10A fuse. Replace the fuse with one of the same value only! The cause may be operation of the submersible electrofisher at excessive power level or catastrophic circuit failure (but <u>not</u> short- circuiting of the electrodes). If a second fuse blows, repair in the field is probably not an option. Bypassing the interrupted fuse will cause damage to batteries and circuitry.
   (c) Open-circuit in integrated circuit U9 (most likely) or multiple failures elsewhere. Repair in the field not an option.

2) Electrofisher has no apparent effect on fish; no buzzer or neon lamp <u>but</u> amber power monitor lamp is lit.
   (a) Faulty 'trigger' cabling. Ensure that the connector at the 3 post terminal J3 on the underside of the board is well seated. Also check the integrity of the intermediate (brown thermoplastic) connectors associated with this wiring.
   (b) Fault inside trigger handle. Causes could be: open circuit in wiring; dislocation of reed switch; flooding of the handle (with possibly non-repairable damage to the buzzers). The buzzers are an integral part of the enabling circuit. The trigger handle can be opened by unscrewing the retaining screw for the trigger and twisting out the grey plastic end of the trigger handle (fitted with o-ring seals). The reed switch position can then be examined and any moisture drained and dried with a hair dryer.
   (c) Failure of enabling circuitry on printed circuit board.
   Repair in the field not an option.

3) Electrofisher has no apparent effect on fish; red lamp flashing.

   (a) Battery voltage has dropped below minimum acceptable level (approximately 21 V), enabling the low battery lock-out circuit. Recharge battery.

(b) Transient condition has triggered the low battery lock-out circuit (e.g., turning off the submersible electrofisher and immediately turning it on again). Turn off the power, wait a moment (>10 s), and turn it on again.

4) Electrofisher has no effect, or marginal effect, on fish; all indicators (buzzers; neon high-voltage lamp; power monitor lamps) behave 'normally'.

(a) Marginal operation may be caused by the inadvertent selection of too low a voltage for water conductivity. The power monitor lamps provide a relative indication of power (watts) output: widely different electrode geometries may not show the same correspondence with the power monitor 'levels' (amber, green and red)... and fish of different sizes and species do not exhibit the same response to a supposedly ideal setting. Let fish response be your primary guide.
(b) No effect with increasing voltage suggests bad wiring or an opened pulse circuit. Check wire connections to the electrode terminals and ensure that the connector at the 5 post terminal J4 on the underside of the board is well seated.

Failure of the pulse output circuit is not a field-repairable condition.

5) OTHER

The submersible electrofisher electronic circuitry has performed reliably during testing and field trials. Circuit complexity suggests many hypothetical failure modes. A volt-ohmmeter (preferably digital) should accompany the submersible electrofisher into the field. This instrument can be used to check for wiring continuity and battery voltage. A thorough in-house physical and electrical check of the submersible electrofisher before field use is also recommended.

ACKNOWLEDGMENTS

Funding for the development of the submersible electrofisher was provided by the Department of Supply and Services under the unsolicited proposal program (UP-A7-038). Mr. Terry Curran, Institute of Ocean Sciences, Sidney, B.C. provided continual encouragement and support for the concept and development of the submersible electrofisher.

8.0 REFERENCES

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APPENDIX 1

Glossary of Electrical Terms

Glossary of Electrical Terms

Anode: the positive electrode

Cathode: the negative electrode

Circuit: complete path of an electric current including the source of electric energy.

Conductivity (c). The ratio of density of the unvarying current in a conductor to the voltage gradient that produces it; common units of measurement are mhos per centimetre or siemens per centimetre.

Conductance (G) The measurement of the ability of a component to conduct electricity; the reciprocal of resistance; unit of measurement is the seimen or mho.

Current (I): The rate of electrical charge flow in a circuit. The practical unit is the ampere, which is one coulomb per second.

Current Density (J): The ratio of a current to the crossectional area of its path in a plane perpendicular to the direction of the current.

Deadman Switch: a switch requiring constant pressure to supply electrical current to the circuit.

Electrical charge (Q): A fundamental property of matter than can be classified as a fundamental physical quantity. The practical unit is the coulomb. The electron, the smallest charge identified in nature, has a magnitude of 1.6×10^{-19} coulomb.

Power (P): The rate of doing work or the energy per unit of time. The practical unit is the watt, which is one joule per second.

Power density (D): The power or energy per unit of time dissipated in a given volume of material; the unit of measurement is watts per cubic centimetre.

Resistance (R): The ability to react to the flow of AC or DC with an opposition to the flow of current. Also, the ratio of the applied voltage to the induced current that it produces. The unit of measurement is the ohm.

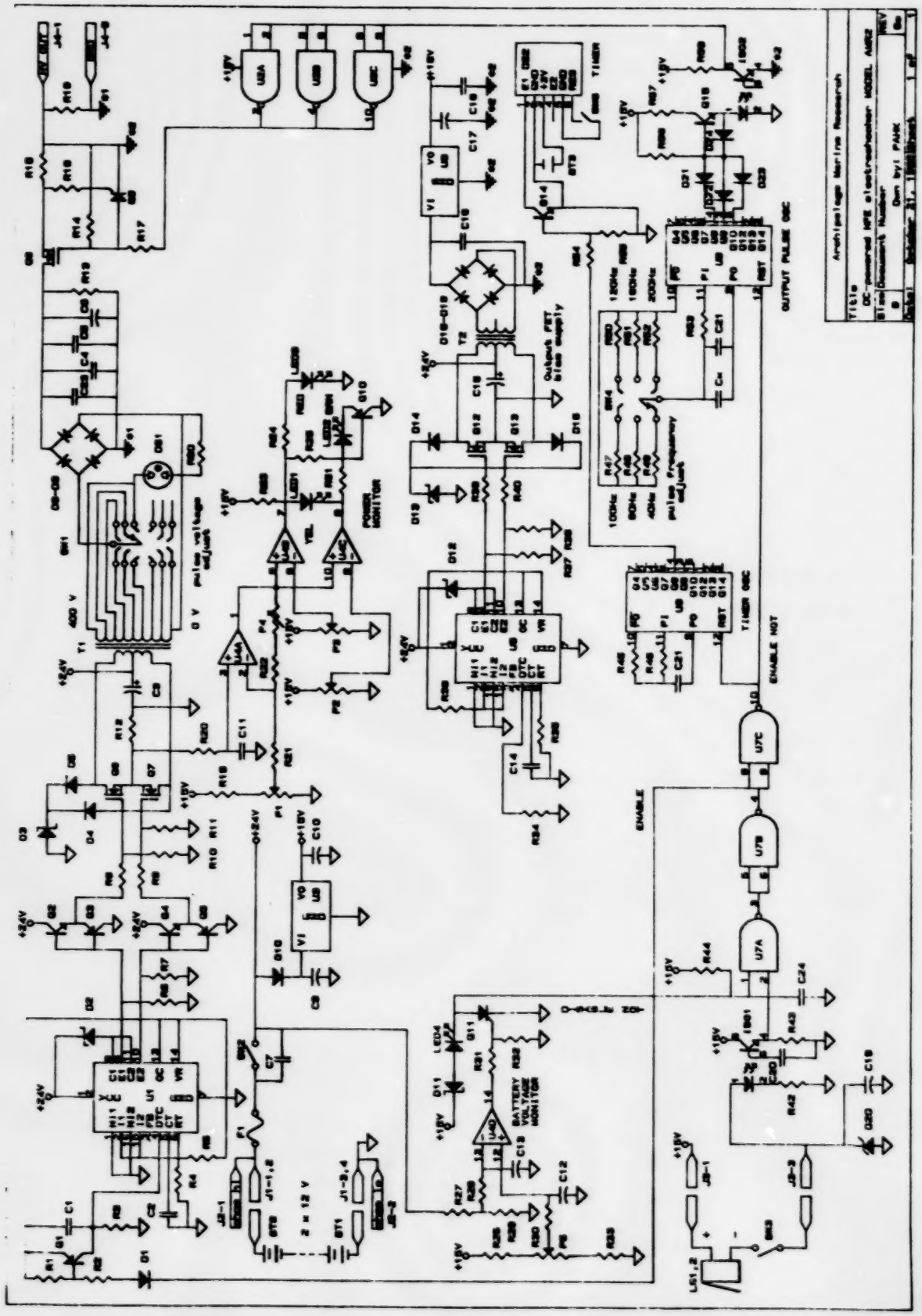
Resistivity (r): The reciprocal of conductivity. The common unit of measurement is the ohm-cm.

Volts or Voltage (V) The energy per unit of electrical charge. The volt is the unit of measure where one volt is one joule per coulomb.

Voltage gradient (E): The rate of change of voltage with distance. Also, the force per unit of electrical charge. The common unit of measurement is volt per centimetre.

APPENDIX 2

Technical Documentation,
including circuit diagram, of the
prototype submersible electrofisher


Archipelago Marine Research
DC-powered HFE electrofisher MODEL AMP2
Drawn by: PARK
OUTPUT PULSE OSC
TIMER OSC
ENABLE HOT
ENABLE
POWER MONITOR
BATTERY VOLTAGE MONITOR
pulse voltage adjust
pulse frequency adjust
Output FET bias supply
400 V
0 V
2 x 12 V

Technical Documentation

Description of Electrical Circuit:

The main electrical circuits are:
- power conversion circuits
- an output pulse circuit
- control and monitoring circuits

Refer to the accompanying electrofisher schematic diagram.

1) Power conversion circuits:

Two DC to DC conversion circuits exist. Both circuits operate at 80 KHz and feature output isolation.

The high voltage circuit steps up the 24 V battery voltage to one of 8 discrete voltages, 0 to 400 V, selected by switch SW1 from multiple-tapped transformer T1. T1's ferrite core is over-sized to ensure cool operation and avoid saturation. The high voltage supply operates only when the electrofisher output is enabled.

The low voltage circuit converts the battery voltage to an isolated output of the same value. This isolated voltage provides a 'floating' bias supply to turn on output transistor Q8. The low voltage circuit operates continuously while the electrofisher power is on.

2) Output pulse circuit:

The output pulse generating circuit employs a variable frequency oscillator with a fixed duty cycle of 12.5%. This circuit provides, via optical isolation, the timing for the 15 V square pulses that drive output transistor Q8.

SCR Q9 detects the voltage drop across current sampling resistor R15 and removes the output voltage when the output current exceeds 6.5 amperes. An indefinite short-circuit at the output may be endured as a consequence.

3) Control and monitoring circuits:

a) Trigger circuit. A magnetic reed switch inside the trigger handle activates a pair of buzzers, also inside the handle, upon depression of the 'trigger'. This circuit action, via optical isolation, enables the high-voltage power supply and the output pulse circuit. A neon lamp connected to the transformer's 400 V winding provides a visual indication of the presence of the high voltage. The buzzers alert the user and assistant without deflecting their attention from electrofishing activity.

b) Elapsed time indicator. An LCD counter module, clocked by a trigger-enabled oscillator, times electrofishing effort in hundredths of a second. Closure of a reed switch, activated by a magnet held against the electrofisher faceplate, resets the counter.

c) Power monitor. Two comparators drive amber, green and red LED lamps providing a relative three-level indication of power expended at the electrode (or power drawn by the high-voltage power supply without regard for power conversion losses). The red lamp may not turn on in low conductivity water. Based on experience gained in tests and field trials, the 'acceptable' (green) level was established at 225 peak watts (by adjusting potentiometer P2) and the 'excessive' (red) level at 350 peak watts (by adjusting P3).

d) Battery voltage monitor. This comparator circuit disables the trigger circuit when the battery voltage drops below 21 V (i.e., 10.5 V per battery). A flashing red LED lamp signals this condition. Recharging the batteries at this point will prevent damage to the lead-acid cells.

e) Circuit Protection.
Output: Indefinite electronic short circuit protection ($I \geq 6.5$ A) of output.
General: Batteries and circuitry protected against prolonged excessive power draw by a 10A quick-blow fuse.

DC-powered Electrofisher

Electrical Parts List

REF : Circuit diagram, Sheet 1 of 1

Part #	Description
BT1,2 ***	12 V/6Ah battery [Sonnenschein 07190432]
BT3	3 V lithium coin cell [#3B980]
C14	7nF, 50 V monolithic ceramic
C2,14,21	1nF, 63 V axial polystyrene
C3	2200 µF, 50 V axial electrolytic
C4,5	0.47 µF, 630 V axial polyester [Siemens]
C6	40 µF, 500 V axial electrolytic [Sprague]
C7,16,18,24	0.1 µF, 50 V monolithic ceramic
C9	100 µF, 50 V radial electrolytic
C10	100 µF, 25 V radial electrolytic
C11,12,15,17,19	10 µF, 35 V radial tantalum
C13	2.2 µF, 35 V radial tantalum
C20	10 nF, 50 V monolithic ceramic
C22	100 pF, 63 V axial polystyrene
C23	10 µF, 1 KV disc ceramic
Cx	'padding' capacitor for C22
D1,21,22,23,24	1N4148 small signal diode
D2,12	1N5236B 7.5 V 1 W zener
D3	1.5KE51A transient voltage suppressor
D4,5,14,15,16,17, 18,19	1N4936 1A @ 400 V fast recovery rectifier
D6,7,8,9	GI856 3A @ 600 V fast recovery rectifier
D10	1N4007 1A rectifier
D11	1N5240B 10 V 500 mW zener
D13	1N4757 51 V 1 W zener
D20	1N5223B 2.7 V 500 mW zener
DS1	C2A (NE-2H) neon lamp
DS2	Hengstler model GO 706-100 3 Vdc counter module [Electro Sonic Inc]
F1	AGC10 fuse
ISO1,2	MCT275 optoisolator

J10.156" 4 pos locking header [Panduit]
J20.156" 2 pos locking header
J30.156" 3 pos locking header
J40.156" 5 pos locking header

LED1	HLMP3401 yellow T1 3/4 led
LED2	HLMP3507 green T1 3/4 led
LED3	HLMP4700 red T1 3/4 led
LED4	TLBR5410 blinking red T1 3/4 led
LS1,2 ***	buzzer(s), 70 mA @ 12 V [Radio Shack #273-051A] (two buzzers in parallel)
P1	500Ω, 20-t, cermet trimmer
P2,3	5KΩ, 20-t, cermet trimmer
P4	1MΩ, 20-t, cermet trimmer
P5	1KΩ, 20-t, cermet trimmer
Q1,3,5,10	2N2907 or PN200
Q2,4,14,15	2N2222 or PN2222
Q6,7	IRF540, 100 V, 27A MOSFET
Q8	IRF840, 500 V, 8A MOSFET
Q9,11	2N5064, SCR
Q12,13	IRF510, 100 V, 4A MOSFET
R1,2,3,19,29,31,34, 43,44,51,52,54,55, 56	10KΩ, ¼ W, cf
R4,35	6.8KΩ,¼ W, cf
R5,36	47KΩ, ¼ W, cf
R6,7	470KΩ, ½ W, cf
R8,9	75Ω, ¼ W, cf
R10,11,14,21,25,61	4.7KΩ, ¼ W, cf
R12	approx. 16mΩ (3 1" lengths of 23 gauge wire in parallel)
R13	330KΩ, 2 W, ww or mf
R15	0.12Ω, 2 W, mf
R16,17,37,38	1KΩ, ¼ W, cf
R18	330KΩ, 1 W, mf
R20,28,30,49	100KΩ, ¼ W, cf
R22	750KΩ,¼ W, cf
R23,24,59	750Ω, ¼ W, cf
R26	20KΩ, ¼ W, cf
R27,47	30KΩ, ¼ W, cf
R32	2KΩ, ¼ W, cf
R33	9.1KΩ, ¼ W, cf

R39,40	27Ω, ¼ W, cf
R42	120Ω, ¼ W, cf
R45,51	15KΩ, ¼ W, cf
R46	150KΩ, ¼ W, cf
R48	39KΩ, ¼ W, cf
R50	22KΩ, ¼ W, cf
R52	8.2KΩ, ¼ W, cf
R53	82KΩ, ¼ W, cf
R57	820Ω, ¼ W, cf
R60	680K, 1 W, ww or mf
SW1	1 pole 11 pos non-shorting rotary switch [Centralab PA-1001]
SW2	SPDT toggle switch 15 A [Armaco ST2713]
SW3 ***	reed switch, magnet-activated
SW4	1 pole 11 pos shorting miniature rotary switch, pc-mount [Grayhill 56 series]
SW5	reed switch, magnet-activated
T1	custom wound high power transformer
T2	custom wound low power transformer
U1,5	TL594 switching regulator
U2,7	4093 quad Schmitt NOR
U3,6	7815 U
U4LM324	quad op-amp
U8,9	4060 oscillator & counter
misc	battery holder, pc-mount [Keystone]

NOTES :

1) C8 and R41,58 & 59 do not exist.
2) Components marked with '***' are external to the pc board.

APPENDIX 3

Letter from Workers' Compensation Board

APPENDIX 3

WORKERS' COMPENSATION BOARD OF BRITISH COLUMBIA

Mr. Brian Emmett
Archipelago Marine Research Ltd.
#11 - 1140 Fort Street
Victoria B.C.
V8V 3K8

October 17 1990

Dear Mr. Emmett,

I apologize for my tardiness in responding to your submission of the submersible electrofisher operating procedures.

I thank you for the opportunity to examine them and I am pleased to inform you that I can see nothing which conflicts with current W C B policy on electrofishing.
I note that the Electrical Safety Branch state that they do not have the expertise to approve devices such as yours, and to the best of my knowledge there is no legislation which requires C S A approval for a piece of equipment that you manufacture for your own use.
I wish you every success in your endeavour.
Sincerely,

Keith A. Haigh
Research and Standards Department
Occupational Safety and Health Division

LIST OF FIGURES

Figure 1. Voltage discharge pattern of pulsed direct current.
Duty cycle = t/T; Pulse frequency = # of voltage discharges per unit time.
Pulsed Power = DC Power x Duty Cycle

$$= \frac{V^2}{R} \times \frac{t}{T}$$

Figure 2. The basic components of electrofishing equipment and their configuration in the submersible electrofisher.

Figure 3. Top view of the submersible electrofisher.

Figure 4. Submersible electrofisher with plexiglass cover and circuit board removed. Note the plug connections, which are described in Section 5.1.1.

Figure 5. Block diagram illustrating the electrical components of the submersible electrofisher.

Figure 6. Quadrat electrode unit used for sampling fish from bottom substrate.

Figure 7. Wand electrode unit used for sampling free-swimming fish.

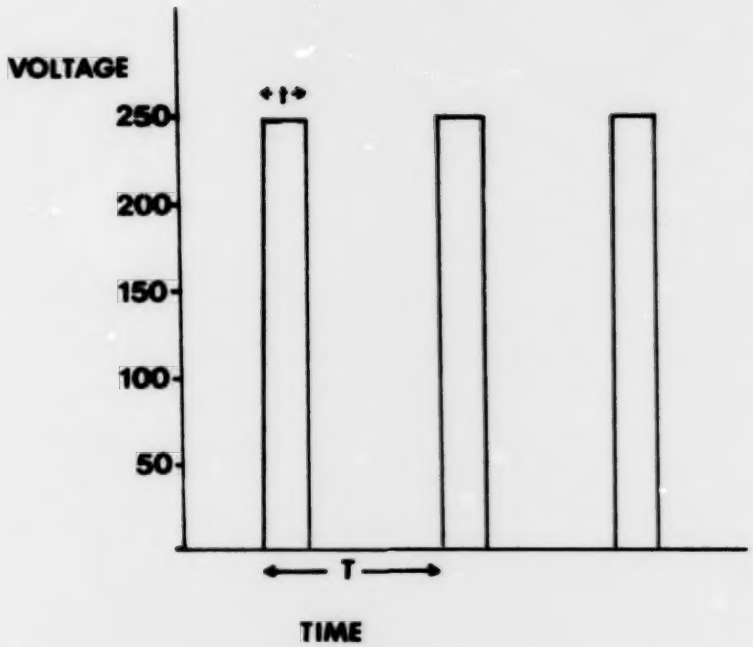


Fig. 1. Voltage discharge pattern of pulsed direct current.
Duty cycle = t/T; Pulse frequency = # of voltage discharges per unit time.

$$\text{Pulsed Power} = \text{DC Power} \times \text{Duty Cycle} = \frac{V^2}{R} \times \frac{t}{T}$$

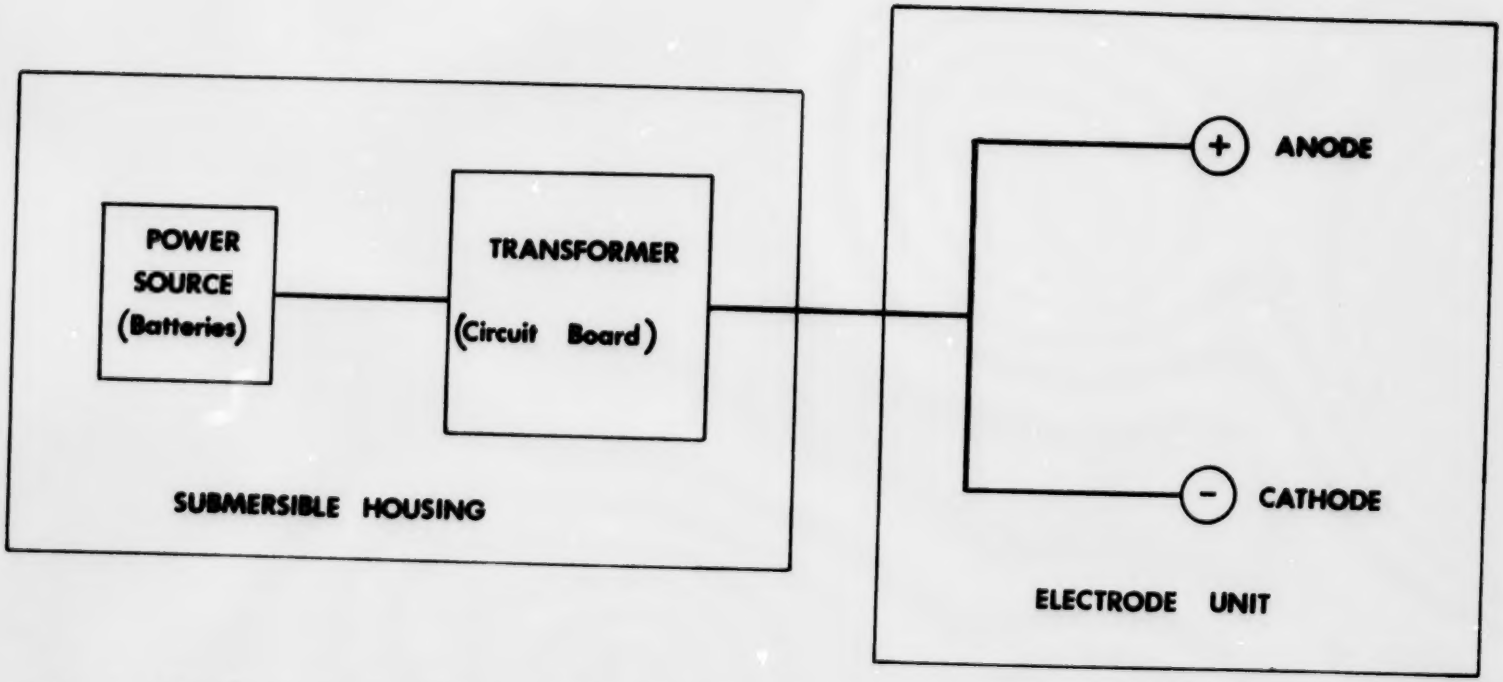


Fig. 2. The basic componenets of electrofishing equipment and their configuration in the submersible electrofisher.

Fig. 3. Top view of the submersible electrofisher.

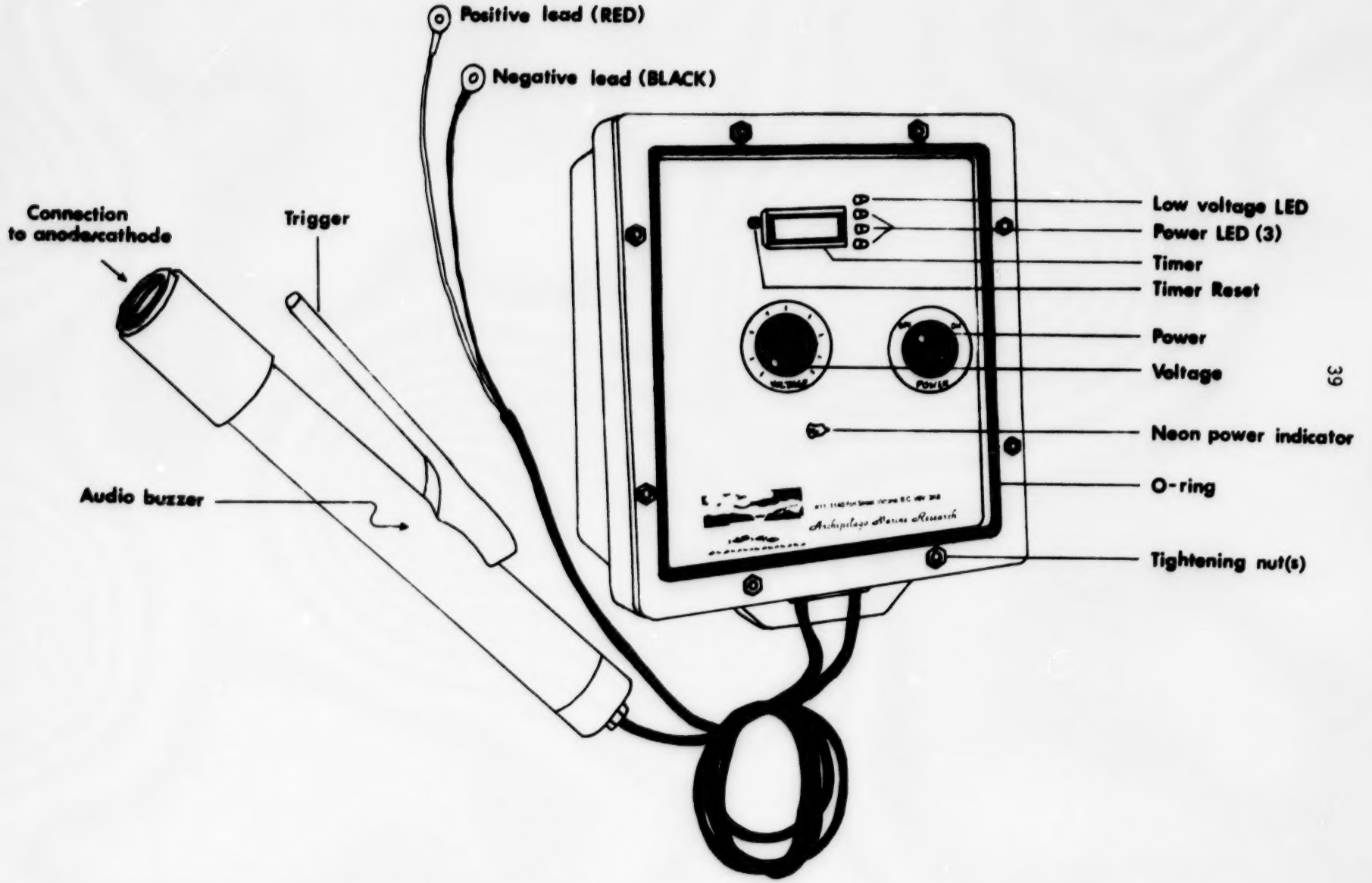
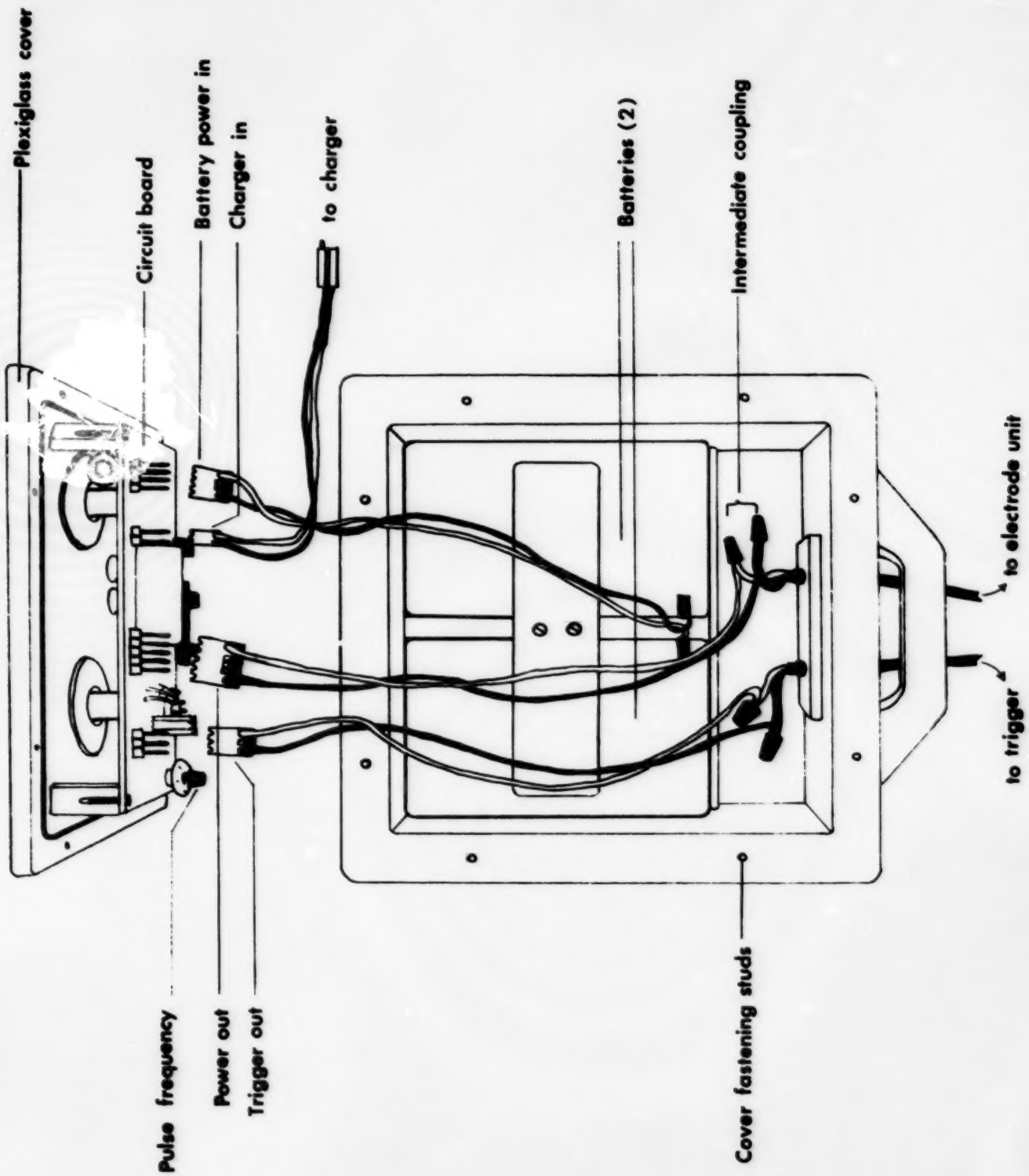

Positive lead (RED)
Negative lead (BLACK)
Connection to anode/cathode
Trigger
Audio buzzer
Low voltage LED
Power LED (3)
Timer
Timer Reset
Power
Voltage
Neon power indicator
O-ring
Tightening nut(s)
Archipelago Marine Research

Fig. 4. Submersible electrofisher with plexiglass cover and circuit board removed. Note the plug connections, which are described in Section 5.1.1.


Plexiglass cover
Circuit board
Battery power in
Charger in
to charger
Batteries (2)
Intermediate coupling
Pulse frequency
Power out
Trigger out
Cover fastening studs
to trigger
to electrode unit

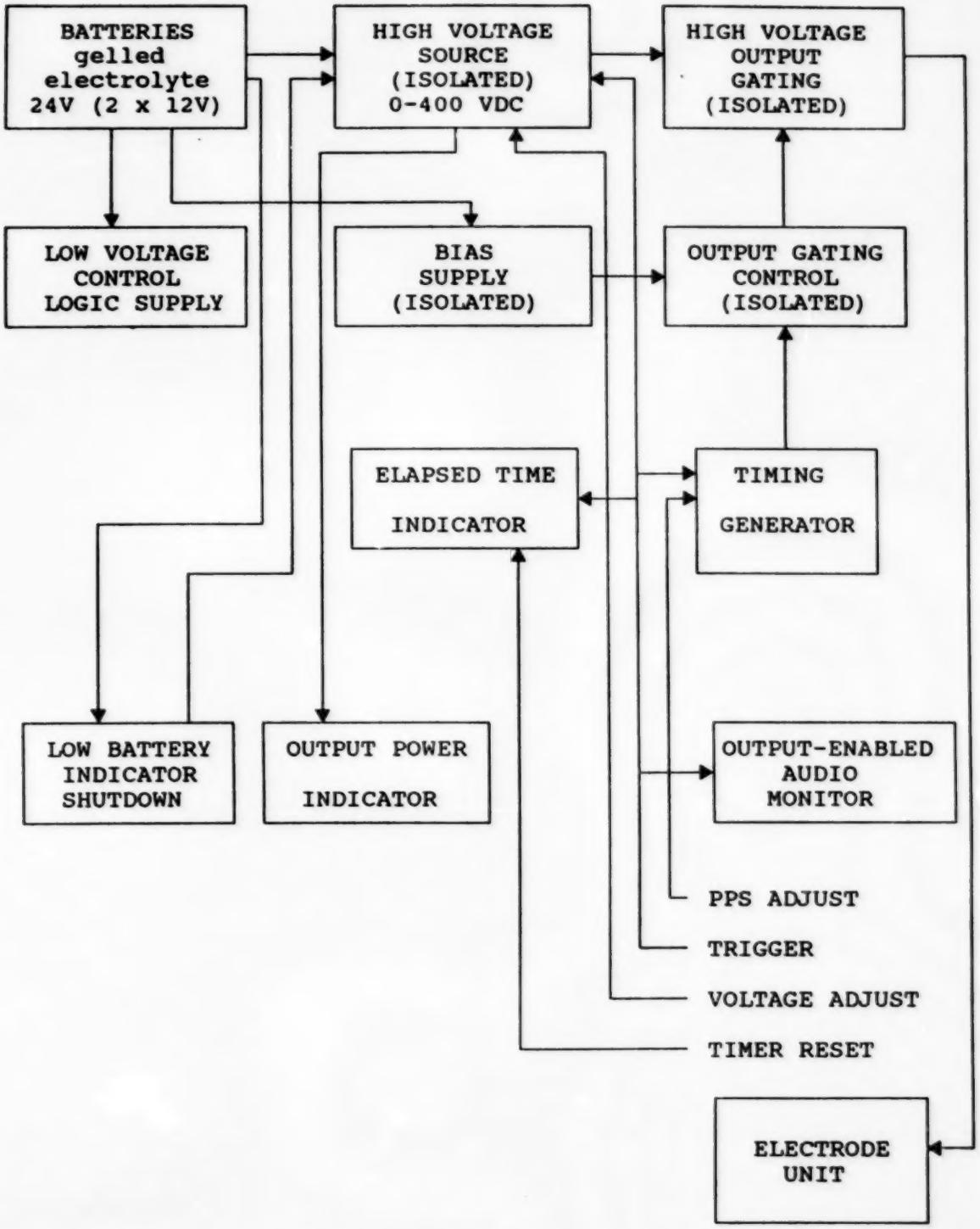
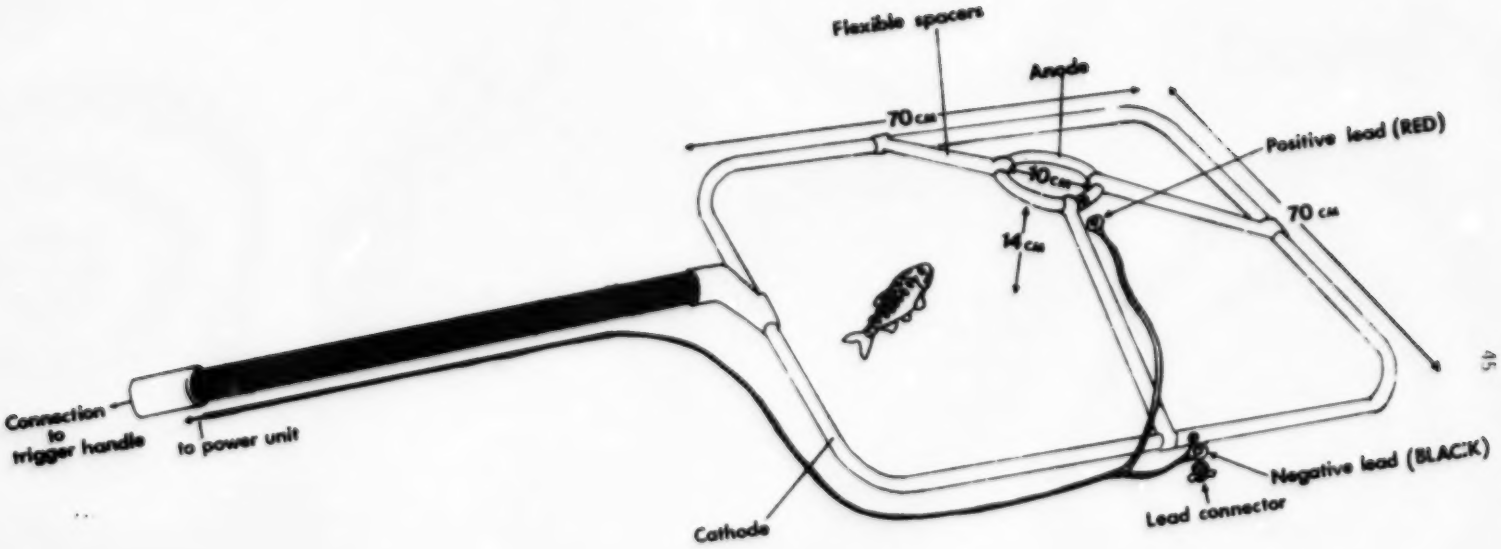


Fig. 5. Block diagram illustrating the electrical components of the submersible electrofisher.

Fig. 6. Quadrat electrode unit used for sampling fish from bottom substrate.


Flexible spacers
Anode
70 cm
Positive lead (RED)
10 cm
70 cm
14 cm
Connection to trigger handle
to power unit
Cathode
Negative lead (BLACK)
Lead connector

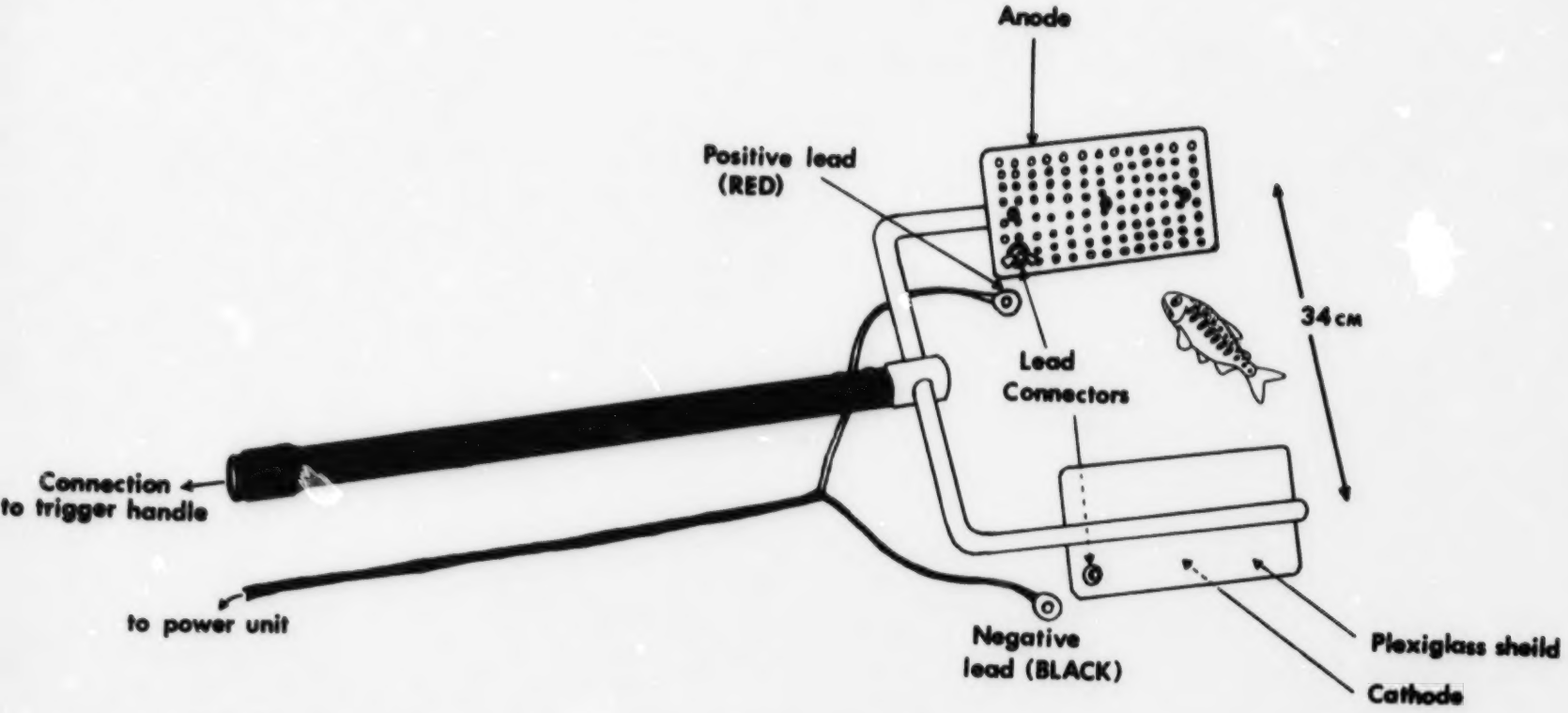


Fig. 7. Wand electrode unit used for sampling free-swimming fish.